FLUOR

Fluor Marine Propulsion, LLC
Post Office Box 79
West Mifflin, PA 15122-0079

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August 16, 2022

MEETING SUMMARY

Meeting Date	June 28, 2022
Leader/Organization	N. S. Plate / NR 08G
Attendees	NR 08G: N. S. Plate; A. S. Hunt NRC: B. White; J. Borowsky; L. Howard NNL: S. Fiscus; C. B. Haslett; J. T. Maciupa; S. M. Ciez; A. L. Primas; J. M. Dugan; M. N. Sexton; M. T. Schifano; J. T. Hayduk

Subject: M-140 Shipping Container; Teleconference to Discuss Nuclear Regulatory Commission Questions on the D2W and S6W Spent Fuel in the M-140 Safety Analysis Reports for Packaging; For Information (U)

Dear Sir:

PURPOSE

In the Reference (a) letter, Naval Reactors (NR) provided the Nuclear Regulatory Commission (NRC), for review and concurrence, the D2W and S6W Spent Fuel in the M-140 Safety Analysis Reports for Packaging (SARPs). NR, NRC, and Naval Nuclear Laboratory (NNL) personnel met on June 28, 2022 (via Bridgeline) to discuss preliminary NRC questions on the thermal and containment chapters from the D2W and S6W Spent Fuel in the M-140 SARPs. This meeting summary documents the questions and responses during the discussion and supports generation of the NRC Safety Evaluation Report and potential Requests for Additional Information if deemed necessary by the NRC.

DISCUSSION

The following is a summary of the NRC questions as well as the responses provided by NR and NNL from the meeting on June 28, 2022.

<u>Discussion of the D2W SARP</u>:

Topic 1: Why are the spacer screw assembly drawings not included in the SARP?

NNL identified that the spacer screw assembly is conservatively neglected in the normal conditions of transport (NCOT) and hypothetical accident conditions (HAC) evaluations. Therefore, the drawings were not included.

Topic 2: Is the design temperature different from the allowable temperature? Did the temperatures in Table 2.6-1 exceed the allowable temperatures?

NNL identified that the temperatures did not exceed the allowable temperatures. The design temperatures are the temperatures that are used to evaluate the structural components in the M-140 Core Independent SARP. The D2W temperatures slightly exceeded some design temperatures. However, the D2W temperatures did not exceed the allowable temperatures, and are justified to be acceptable. Specifically, the closure head seal temperature does not exceed the maximum service temperature limit for the seals during NCOT. Table 2.6-1 in the D2W Core Dependent M-140 SARP concluded a maximum closure head seal temperature of 199°F. Section 4.1.3.2 of the Core Independent SARP states that the service temperature of this seal is -65°F to 250°F.

Topic 3: How much margin is there with the results of NCOT and HAC? Can there be a semi-quantification “margin is well over x%”?

NNL identified thermal fuel performance levels are less than half of the applicable limit for this cargo. The model has greater than 50°F of temperature margin to meeting fuel performance limits.

Topic 4: On Page 3.1, the maximum decay heat modeled in each port is difficult to understand. Is the model bounding because of how the container is assumed to be loaded?

NNL identified that the model uses a conservative decay heat that bounds the actual shipment configuration.

Topic 5: There are various heat transfer modes listed in Table 3.3-2. What is the difference between gap conductance and conduction and has this method been used before?

NNL identified gap conductance is modeled as a physical gap between solid surfaces, whereas conduction occurs through a solid when air is modeled as a part. Both gap conductance and conduction have been used before in NNL analyses and provide equivalent heat transfer in the model.

Topic 6: Section 3.3.1.3 states that a mesh sensitivity study was performed, but no acceptance criteria is listed. What is the acceptance criteria?

NNL identified for the Section 3.3.1 model, mesh sensitivity studies are performed until further refining the mesh provides diminishing returns on the change in temperature. Mesh studies showed the variation of temperature was within 2°F for the refined meshes, which is acceptable relative to the level of conservatism in the models.

Topic 7: What is the acceptance criteria for the energy balance for the model in Section 3.3.1?

NNL identified the amount of energy generated in the model was compared to the applied decay heat load. The total heat load of each fuel cell in the D2W model was within 0.03% of the applied heat load. For S6W, the conservative heat load application results in the model conservatively producing 5-10% over the expected heat load.

Topic 8: For the HAC transient in Section 3.4, was a timestep sensitivity study performed?

NNL performed time step sensitivity studies to ensure that the time steps are small enough to capture the transient temperature profile appropriately; they are performed similarly to spatial mesh studies where the time step is varied until there is no more than a 2°F difference in peak HAC fuel temperatures. The 2°F temperature difference is acceptable relative to conservatisms in the models.

Topic 9: How are the fins modeled in Section 3.3.1? Is there a thermal/contact resistance between the fins and the container?

NNL identified that the fins (0.5 inch thick) are welded to the container via double bevel welds so there is no contact resistance. The fins are modeled in Section 3.3.1 as a separate part and attached to the container in perfect contact, meaning there is no thermal resistance between the fins and the container body.

Topic 10: For the heat transfer correlations provided in Appendix 3.5.4, is the effect of the fins accounted for twice?

NNL identified the effect of the fins is not accounted for twice; two reduction factors (factors that conservatively reduce heat transfer through components which results in higher predicted temperatures) are applied to convection coefficients to address separate issues. The 20% reduction originates from NNPP design basis governing instructions and account for variation in the empirical data used to create the correlation. The 25% reduction applies to convection in the finned region to account for the close spacing of the fins (i.e., converging boundary layers). The basis for the 25% reduction originates from a literature article testing flow between vertical plates; internal studies show this reduction has a minimal impact to temperatures (<5°F). Therefore, the applied convection coefficient for the fins is defined as 0.75 x 0.8 x h.

Topic 11: Why are the correlations between D2W and S6W different despite being a similar package and was a comparison between the correlations completed?

NNL identified the original TRUMP models in the S6W SARP used correlations from the Oak Ridge National Laboratory (ORNL) Cask Designer's Guide. When the new Abaqus model was created to calculate fuel temperatures, the original correlations were maintained. Regarding D2W, the new Abaqus model was created to provide fuel and structural temperatures and used the latest design basis correlations from NNPP governing instructions. Both sets of correlations are appropriate to capture convection heat transfer and comparisons done in other internal NNPP analyses show minor variations to external temperatures that do not result in exceeding any design temperatures in the SARPs.

Topic 12: Clarify how the sensitivity study in the horizontal orientation was performed and how the horizontal orientation was different from the vertical orientation.

NNL identified both the vertical and the horizontal orientations are considered for the HAC thermal evaluation. While the performance of cooling fins in the vertical orientation is known, less is known regarding the performance of cooling fins in a horizontal orientation. Given this uncertainty, internal scoping studies were performed using conservative assumptions for the capture and release of energy for the subsequent fire and post fire conditions in the horizontal orientation.

During the fire, the horizontal orientation model conservatively assumes the fins are present, and the convection correlation is that of the vertical orientation; this maximizes the penetration of the fire into the finned region and the energy captured during the fire. After the fire, the horizontal orientation model conservatively assumes no convection on the outside surface of the container, minimizing energy release.

The applied conservative assumptions provide an upper bound on the performance of fins in the horizontal orientation. However, in order to yield package temperatures that were not overly conservative, other conservative modeling assumptions were relaxed for the horizontal orientation model.

The sensitivity study presented in Section 3.4.1 of the SARP relaxed two conservative assumptions; 1) the application of the solar load, and 2) the inclusion of fuel upper structural components. First, the applied solar load was relaxed to a 10 CFR 71 compliant 12 hour period application, rather than the originally applied full 24-hour period application from the vertical orientation model. Second, fuel upper structural components were added to the fuel model, which act to distribute energy away from the fuel region post fire, and reduce fuel temperatures, compared to the vertical orientation model.

While the boundary condition assumptions differ between the horizontal and vertical orientation models, both sets of assumptions are conservative. Given the applied conservative assumptions, the vertical orientation model yields higher temperatures than the horizontal orientation, but both orientations produce acceptable temperatures.

Topic 13: In reference to Table 3.3-3 and Figure 3.3-10, how do we know the model is actually bounding?

The primary purpose of the model presented and compared to the test in Figure 3.3-10 was to maximize fuel assembly temperatures, which are shown to be conservative when comparing the analysis and test results for Thermocouples 183 and below in Figure 3.3-10.

As seen in Figure 3.3-10, at the applied decay heat loads of 127,000 Btu/hr and 164,000 Btu/hr, the models do not yield bounding structural temperatures at the upper portions (Thermocouple 185 and above) when compared to the test. The difference is larger at the higher heat load. While these predictions are not bounding; these heat loads are 2.8 to 3.6 times the allowable D2W heat load of 45,000 Btu/hr. At lower decay heats, the temperature difference between the model and the test will decrease.

Internal documentation compared the test data at 127,000 Btu/hr to the analyzed condition in the M-140 Core Independent SARP at 75,773 Btu/hr by adjusting test temperatures of the top components to account for the lower decay heat, the higher ambient air (100°F vice 69°F), and the presence of a solar load. The comparison showed that the adjusted test temperatures were bounded by the M-140 Core Independent SARP values, confirming the appropriateness of using the M-140 Core Independent SARP temperatures for structural calculations.

Topic 14: In reference to Figure 3.3-11 and 3.3-12, have we seen such a large effect with regard to solar load on other projects?

NNL identified other projects show similar impacts because of insolation (i.e. Figures 3.3-6 and 3.3-7 of the S8G M-140 SARP show about 10°F difference in fuel cell assembly temperatures due to insolation at 41,411 Btu/hr). Applying the full solar load to a steady-state model instead of a transient model applying insolation for 12 hours on and 12 hours off per 10 CFR 71 increases the impact to temperatures.

Topic 15: Thermal expansion was considered for NCOT. Was thermal expansion considered for HAC?

NNL identified the D2W SARP did not explicitly address thermal expansion during HAC. Internal scoping studies evaluated thermal expansion during HAC using available temperature and material property data.

Unlike the NCOT evaluation, the thermal expansion of the M-140 container body was not conservatively ignored for the HAC evaluation because the fire directly contacts the cask body. By accounting for container body thermal expansion, a positive clearance is maintained between the module and the bottom of the closure head and the margin to closing the clearance for HAC is greater than the margin to closing the clearance for NCOT documented in the D2W SARP.

Topic 16: Discussion regarding natural convection in the thermal test and analytical model. Was natural convection omitted in the analytical model from Section 3.3.1?

NNL confirmed the analytical model does not include internal natural convection where the test would. Although the analytical model does not include internal natural convection, the analytical model is conservative in regards to the thermal test and is appropriate for use, as discussed in Topic 13.

Topic 17: Figure 3.4-1 in both D2W and S6W SARPs have different temperature profiles. Why were the surface temperatures substantially different?

NNL identified these figures are comparable. Figure 3.4-1 in the D2W SARP includes two curves: one for the tip of the 5-inch fin and one for the base of the fin. The temperature at the tip of the fin is much higher than at the base. Figure 3.4-1 in the S6W SARP only provides a curve at the base of the fin which is comparable to the base of the fin curve in the D2W SARP. The fin tip temperature is much higher due to the small thermal mass of the fins, while the outer vessel surface will not approach the flame temperature due to the significant mass of the steel container coupled with the short duration of the fire.

Topic 18: The absorptivity values are not listed. What are they?

NNL identified the models use the full insolation heat flux values provided in 10 CFR 71.71 which inherently assume an absorptivity of 1.

Topic 19: Reviewing a past M-140 SARP, a discussion of the leakage rate was provided. However, there was no discussion provided in Chapter 4. Why was this excluded?

NNL identified that the section discussing the leakage rate was not included in the D2W SARP because the discussion is provided in the M-140 Core Independent SARP. All of the assumptions used in the bounding M-140 Core Independent evaluation are met with the D2W cargo. The previously reviewed M-140 SARP that included this discussion was the MTS Addendum to the S3G-3 Spent Fuel in the M-140 SARP. The discussion was provided because the MTS addendum did not meet all of the assumptions in the M-140 Core Independent evaluation (i.e. MTS internal pressure was slightly higher than the shipping environment assumed in the M-140 Core Independent evaluation).

Discussion of the S6W SARP:

Topic 20: Similar to the previous D2W question (Topic 3), what is the margin?

NNL identified the model has greater than 100°F of temperature margin to meeting fuel performance limits for NCOT and HAC.

Topic 21: There are two thermal models in Section 3.3, a TRUMP model and an ABAQUS model. How are the models different from the models in the previous SARP revision?

NNL identified that the models are unchanged. Both the TRUMP and Abaqus models have been reviewed and approved by the NRC in previous SARP revisions. The previous SARP revision had separate evaluations for both the prototype and shipboard cores. For this SARP revision, the SARP combined the evaluations using a bounding decay heat that was analyzed in the previous SARP revision. There was no new analysis performed in this SARP revision.

Topic 22: Page 3.3-7 shows a higher thermal conductivity for Zircaloy but shows a higher temperature. Why?

NNL identified the discussion on Page 3.3-7 discusses how the model applies Zircaloy properties to a component with a different material because Zircaloy has a higher thermal conductivity. This application increases the heat transfer from the fueled region (i.e., heat source) to the top of the component to maximize the temperature in that region.

Topic 23: Page 3.3-8 provides a discussion on the minimum temperatures but does not include what the minimum temperature is. Can you clarify what this temperature is?

NNL identified that the minimum temperature for the M-140 container and cargo is -40°F as required by 10 CFR 71 since there is no minimum specified decay heat generation required for shipment. The M-140 does not depend on a minimum decay heat generation rate for safe operation or shipment.

Topic 24: Was the decay heat modeled as a volumetric heat source?

NNL identified that the decay heat was modeled as a volumetric heat source in the ABAQUS model.

Topic 25: Is the allowable seal temperature the same as D2W?

NNL identified the allowable seal temperature is the same for all M-140 cargos with a service range of -65°F to 250°F, as discussed in Topic 2. Table 2.6-1 of the S6W SARP shows that the maximum seal temperature of 161°F is within the service range.

Topic 26: Was water vapor and the radiolysis effect on pressure included in the pressure calculation?

NNL identified that water vapor is included in the pressure calculation, which is based off of the maximum internal pressure calculation in Section 2.10.1.10 of the M-140 Core Independent SARP. The pressure calculation is the sum of the partial pressures exerted by water vapor and non-condensable gases.

Radiolysis is not directly included in the pressure calculation. Other M-140 SARP analyses (e.g., D2W) show the non-condensable contribution increases by 8.1%, so applying 8.1% to the entire internal pressure of 26 psig for NCOT only increases pressure to 28.5 psig which is below the 75 psig NCOT design pressure from M-140 Core Independent SARP.

Additionally, per Section 2.4.4 of the M-140 Core Independent SARP, M-140 shipping containers are sampled during initial venting. No measurable hydrogen has been detected with measuring equipment that has a detectability limit of 0.2%.

Topic 27: Thermal expansion is addressed for NCOT in Section 2.6.1.2. Was thermal expansion addressed for HAC?

NNL identified thermal expansion is addressed in Section 2.7.3 providing the same conclusion identified in Topic 15.

Topic 28: Similar to D2W (discussed in Topic 18), the absorptivity values are not listed. What are they?

The models use the insolation heat flux values provided in 10 CFR 71.71 which inherently assume an absorptivity of 1.

Topic 29: Is there any test data to compare Figures 3.4-1 and 3.4-2?

NNL uses the same M-140 test data to qualify all M-140 SARP models, so the same comparison to the data as in the D2W M-140 SARP would be appropriate for this model as well. The comparison to test data during NCOT for S6W would show similar conclusions as Figure 3.3-10 of the D2W M-140 SARP. The setup of the D2W and S6W M-140 SARP Abaqus models both exclude upper structural components of the fuel assemblies and internal natural convection, so the temperatures in the fueled region are conservative, and temperatures at the top of the container will be lower than the test data. The same arguments justifying the D2W M-140 SARP model apply here since the CoC for S6W cargos has a lower allowable decay heat of 41,712 Btu/hr (vice 45,000 Btu/hr for D2W).

CONCLUSION

The discussion above summarizes the meeting held on June 28, 2022 between NR, NRC, and NNL on the D2W and S6W Spent Fuel in the M-140 SARPs. NR (Plate) agrees that this accurately summarizes the topics discussed with the NRC and are clarification in nature. If deemed required, NRC will provide NR with requests for additional information to formally disposition technical questions on the SARPs provided for NRC review and concurrence in the Reference (a) letter.

JOHN MACIUPA

Digitally signed by maciupjt@nnpp.gov (1000025275)
Date: 2022.08.16 06:54:14 -04'00'

John T. Maciupa, Engineer
Shipping Container Analysis
Reactor Servicing Systems

References:

(a) G#C21-00922, dated March 23, 2021, M-140 Spent Fuel Shipping Container – Nuclear Regulatory Commission Certificate of Compliance USA/9793/B(U)F-85; Request for Renewal; S3G Core Basket Disposal Container - Nuclear Regulatory Commission Certificate of Compliance USA/9786/B(U); Request for Cancellation (U)